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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
G01B 11/30, G01N 21/57, 21/88

A1

(11) International Publication Number: WO 98/36240

(43) International Publication Date: 20 August 1998 (20.08.98)

(21) International Application Number: PCT/SE98/00226

(22) International Filing Date: 10 February 1998 (10.02.98)

(30) Priority Data:
9700539-1 17 February 1997 (17.02.97) SE

(71) Applicant *(for all designated States except US)*: AB VOLVO [SE/SE]; S-405 08 Göteborg (SE).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: LARSSON, Peter [SE/SE]; Persikogatan 108, S-421 56 Västra Frölunda (SE). LARSSON, Anders [SE/SE]; Omvägen 5B, S-412 75 Göteborg (SE). MAX, Erland [SE/SE]; Norra Vaktmansgatan 31, S-426 68 Västra Frölunda (SE).

(74) Agents: GRAUDUMS, Valdis et al.; Albihns Patenbyrå Göteborg AB, P.O. Box 142, S-401 22 Göteborg (SE).

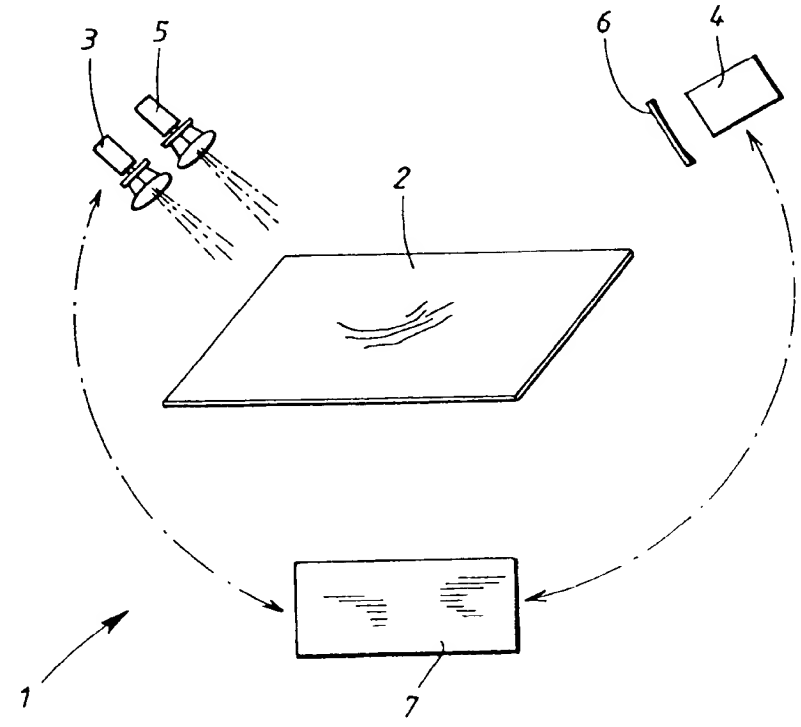
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: METHOD AND DEVICE FOR MEASURING AND QUANTIFYING SURFACE DEFECTS ON A TEST SURFACE

(57) Abstract

The invention relates to a method and a device for measuring and quantifying surface defects, such as defects of polished surfaces. The method and the device according to the invention may be applied for measuring and quantifying so-called polishing roses, which may arise in connection with polishing of, for example, painted sheet metal details within the motor car industry, but can also be utilized for other similar applications. When the invention is performed, a device comprising at least one light source (3, 5), at least one camera (4), and at least one central unit (7) having image analysis functions and control functions, is utilized. The method according to the invention is characterized in that at least two partial images are recorded with at least one camera (4), while illuminating the test surface with parallel light or spot light, wherein the angles of incidence of the light in relation to the test surface (2) and/or the location of the camera (4) or cameras, are different when recording different partial images, whereafter recorded partial images are processed in at least one central unit (7). Thereafter, one or several difference images are produced from the partial images and are utilized for determining the degree of surface defect on the test surface (2).



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TITLE:
Method and device for measuring and quantifying surface defects on a test surface.

TECHNICAL FIELD:

The present invention relates to a method and a device for measuring and quantifying surface defects, such as defects on polished surfaces, by means of optical registration with subsequent image analysis and image processing.

The method and the device according to the invention are primarily applicable for measuring and quantifying surface defects in the form of so-called polishing roses, which may arise in connection with polishing of, for example, painted sheet metal details within the motor car industry. However, the method and the device according to the invention may also be utilized for other similar applications, for example in connection with rubbing or grinding.

In this context, the expression "polishing roses" refers to a certain type of surface defects which have arisen during polishing or other similar surface finishing, such as rubbing or grinding. The polishing roses may adopt several different shapes, depending on under which circumstances they have arisen.

The method practised by means of the device according to the invention may replace the manual, visual examination, which previously has been used for quality testing and assessment of surface defects such as polishing roses, within the applications where a painted surface with a smooth and glossy surface finish is required.

BACKGROUND OF THE INVENTION:

Within the vehicle manufacturing industry (motor car industry), ever increasing demands are made today on the quality of the end product, something which has resulted in the use of more and more advanced systems for quality testing and quality control.

As is well-known to the person skilled in the art, a modern passenger car or truck consists of a plurality of components which originate from different production lines, or from different manufacturers, and which step by step are assembled into a vehicle.

Some of these components are constituted of painted sheet metal components which, in the case of visual body components, generally are polished in order to achieve a smooth and glossy surface finish. In certain cases it may also happen that components of polymeric materials (different plastics) are polished for the same reason.

Independently of which stage one has reached in the assembly process, the need sometimes arises for testing the polishing result of a component which has been polished in an earlier step.

Also in connection with product or process development, there is a need to be able to test or evaluate surface finishing results. Such an evaluation may serve as a guide in the choice of, for example, surface finishing equipment, polishing equipment or polishing technique.

Also when developing new paints and car enamels it is of great importance that paints or enamels in which polishing roses arise to a greater extent than is acceptable can be sifted out.

Hitherto, such quality testing of polished surfaces has in principle been done by means of manual, visual assessment of polished test specimens or finished polished components or vehicles.

One great disadvantage with such manual, visual assessment of the polishing result has been that it is dependent on the individual, i.e. only experienced staff with many years of experience from such assessment has been able to perform it.

Another disadvantage has been that the assessment results have not been reproducible or quantifiable, and that the results, furthermore, to a great extent have been dependent on the light conditions at the testing station. The manual, visual assessment of the polishing result has hitherto most advantageously been accomplished outdoors and in brilliant sunshine.

A frequently occurring surface defect which may arise in connection with surface finishing of different components is so-called polishing roses. As mentioned earlier, in this context polishing roses refer to a certain type of surface defects which have arisen during polishing or other similar surface finishing, such as rubbing or grinding. The polishing roses may adopt several different forms, depending on under which conditions they have arisen.

Accordingly, a typical form of polishing roses manifests itself as a so-called holographic image. With a holographic image, it is understood that the image or pattern appears to be situated below the plane of the polished surface when it is observed from one direction, whereas the same image appears to be situated above the plane of the polished surface when the surface is observed from the opposite direction.

Another frequently occurring form of polishing roses manifests itself as a blurred polishing pattern in the surface when this is observed from above. Such a blurred polishing pattern usually appears together with polishing roses of the earlier-mentioned type, i.e. holographic images.

A third form in which polishing roses occur is sharp, thin scratches, which are clearly visible when the angle of observation is perpendicular to the scratches. This form of polishing roses may appear alone, or together with polishing roses of the two above-mentioned types.

Common to all different forms of polishing roses is that they are practically invisible during normal lighting conditions, something which renders detection difficult.

One reason for polishing roses arising is the uneven pressure application which arises in different movements, when a rotating polishing drum or a polishing cloth is moved across the surface which is to be polished with a rotating movement. Also grinding, rubbing, or other forms of rotating or oscillating finishing may cause polishing roses.

Unsatisfactorily often, polishing roses are not discovered until the finished vehicle is subjected to bright sunlight, and are visible only when the polished surface is observed at a certain angle. The problem is more evident for vehicles which have been painted in dark shades than for light-coloured painted vehicles, since the polishing roses are more prominent on dark surfaces than on light surfaces. Since the majority of the positions, in for example an assembly line, where a need for testing of the polishing result occurs, are located indoors, it has hitherto been difficult to determine the presence of polishing roses

before the vehicle has been fully assembled and able to be driven outside for ocular inspection. Accordingly, it is very difficult to continuously check the polishing result of individual sheet metal components before assembly.

Therefore, it is evident that there has long been a need for a reproducible, quantifiable, measurement method for evaluation of the presence of polishing roses or other similar surface defects of polished or in other ways surface finished components. Such a measurement method should further be insensitive to the light conditions which prevail at the testing station, and should be able to distinguish polishing roses from surface defects of other types, which do not originate from the surface finishing.

SUMMARY OF THE INVENTION:

Accordingly, the object of the present invention is to provide a method and a device for measuring and quantifying surface defects on a test surface, by means of optical registration with subsequent image analysis and image processing.

This object is achieved by means of the method and the device according to the invention.

The method according to the invention comprises that at least two partial images are recorded with at least one camera, during illumination of a test surface with light from a spot lighting source or from a light source for parallel light, in such a way that the angle of incidence of the light in relation to the location of said recording camera or cameras is different for different partial images. Thereafter, the recorded partial images are processed in a central unit, wherein a difference image is created by means of calculating the difference between

different partial images. Thereby, the intensity of said manufactured difference image is proportional to the degree of surface defect on the test surface.

Thus, for example by means of photographing the surface with a camera (for example an electronic CCD-camera) under illumination with a first and thereafter with a second light source, and subsequently image-processing the two obtained partial images in an image analyzer, i.e. subtracting one partial image from the other, it is possible to separate the polishing roses from other surface defects which do not originate from the surface treatment operation, using the partial image obtained in this way.

The reason for this is that the alternating light with different angles of incidence causes an optical phenomenon which manifests itself as the visible polishing roses appearing to be displaced backwards and forwards when they are illuminated in turns by the respective light source, whereas other occurring defects, originating from for example the paint or the sheet metal, appear to remain immobile. This phenomenon makes it possible to separate the polishing roses from other surface defects, which of course is of great importance to locating the reason for a possible quality problem.

When practising the invention, the measurement arrangement of the device may be varied in several different ways, as long as the angle of incidence, when illuminating the test surface, is different for different partial images in relation to the recording camera or cameras.

Accordingly, the measurement arrangement may comprise, for example, the use of one single light source but two cameras, or the use of one light source and two images from

the same camera, recorded with the camera in two different positions.

Another alternative measurement arrangement is a mobile light source, which is displaced between different positions in order to obtain different angles of incidence for the light when recording different partial images. In such cases, the mobile light source is preferably combined with a single stationary camera, but may also be combined with one or several different stationary or mobile cameras.

The light sources are advantageously arranged in pairs or in groups of more than two and illuminate the test surface laterally, at an angle which can vary between 0 and 90 degrees. By using several lamp groups, the test surface may alternatingly be illuminated from several different angles in a horizontal direction, enabling the test surface to be illuminated from several different directions without being turned or rotated.

Under certain conditions, it may be necessary or desirable to move or rotate the test surface between different partial images. In such cases, when recording different partial images, different light angles of incidence may be obtained by means of displacing the test surface, instead of displacing the camera or the light source, or by using several cameras or light sources in different positions. The displacement or rotation can be achieved by means of any previously known motion means.

It has been found that the light which is reflected from the polishing roses may be polarized, which in such cases facilitates the detection.

When recording partial images, the camera or the cameras are advantageously placed directly above the test surface

which is to be measured, and is/are preferably focused on the polishing roses, which often do not have the plane of the image in the plane of the test surface.

Independently of which measurement arrangement is used, the light source and the camera may be calibrated by means of placing a diffuse surface (e.g. a white paper) in the intended position of the test surface.

Different lens systems, polarizers and colour filters may be used, in order to get the polishing roses to appear more clearly on the partial images and, thereby, on the final difference image. Optical filtration with colour filters can, for example, be used in order to improve the signal/noise-ratio of the recorded images.

The camera or cameras are preferably electronic cameras (e.g. a CCD-camera) according to prior art. A camera which is to be used when practising the invention can be provided with two apertures on each side of the optical axis. This can be done by means of blocking the lens surface in a suitable way, so that only two image-registration apertures remain through which two images may be recorded simultaneously. A camera which in this way has been equipped with two apertures for recording images only requires the use of one light source, which is the also case when two separate cameras are used.

The intensity of light of the light sources and/or the time of exposure and aperture can be adapted or controlled in order to provide images with a suitable exposure. By utilizing pulsating light sources and short times of exposure, the influence of possibly disturbing light from the surroundings can be minimized.

By means of using carefully adapted settings, as described above, difference images with a sufficiently high resolution to make it possible to detect the occurrence of possible polishing roses can be obtained.

After having obtained a difference image by means of an image processing as described above, the image analyzer calculates a surface A, essentially corresponding to the size of the polishing rose or the polishing roses which have been detected in the image window. The total defect area may, for example, be determined as the sum of all surfaces for which the measured light intensity exceeds a certain threshold value. Also more complicated mathematical formulas or equations can be used in order to estimate the extent of the surface defects.

Furthermore, the image analyzer is made to calculate a measure of the intensity, of the polishing rose or polishing roses I_{ev}, which corresponds to the sum of the light effect within the defect area. By means of inserting the parameters A and I_{ev} in an empirically developed formula, a "mark" is obtained. The empirical formula has been obtained by means of adapting measurement values, which have been obtained by means of the method according to the invention, to marks which have been obtained by means of conventional manual, visual assessment. The marks which are obtained in this way have proved to correlate very well with the results from manual, visual assessment.

The reflectance variation, which is dependent on different intrinsic reflectance of different colours, requires a compensation method for different colours if comparable results shall be obtained.

The angle of observation of the camera or cameras is essential to enabling the empirical formula to provide

marks which correlate with manual, visual assessment. The suitable angle of observation has to be arrived at by trial on location at each testing station.

Trials have shown that, for example, when measuring on polished surfaces which have been painted with metallic paints, there is a maximum allowed angle of observation if it shall be possible to identify polishing roses with the empirical formula. When the angle of observation exceeds the allowed value, the measurement result is heavily impaired, since so-called metallic flakes are projected on the difference images.

There are several methods of increasing the resolution and definition of the partial images, and thereby also the clarity of the final difference images, which are to be used for measuring and quantifying possible polishing roses.

Accordingly, by means of image processing in an image analyzer according to prior art, a background image, i.e. an image which has been recorded with the light source switched off, can be subtracted from each partial image.

Each partial image can also be adjusted with respect to amplification, based on a calibration image for the prevailing combination of camera/light source, or in another way be signal-processed, with the aim of increasing the detection degree of surface defects before the production of difference images.

Also difference images, which have been obtained by means of subtraction between different partial images, may be image-processed in different ways in order to further enhance the polishing roses. Thus, by means of so-called correlation technique, polishing roses which appear at

slightly different coordinates in different partial images can be clarified. Smaller defects such as "spots" and the like can be removed with median filters.

The above-mentioned empirical formula or algorithm, which is used in order to calculate a mark, may instead be constituted of an adapting neuronal net or other mathematic equations.

Accordingly, the method and the device according to the invention provide a reproducible method and a device for measuring and quantifying surface defects, such as polishing roses, which method, in addition, is essentially insensitive to the light conditions which prevail at the time of measurement.

BRIEF DESCRIPTION OF THE DRAWINGS:

In the following, the invention will be described with reference to the attached drawings, in which

Fig. 1 schematically illustrates a preferred embodiment of a device according to the invention,

Fig. 2 shows a difference image obtained by means of the method according to the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS:

In the attached Fig. 1, a preferred embodiment of the device 1 according to the invention is shown, by means of which device the method according to the invention may be practised. The method according to the invention comprises that a test surface 2 first is illuminated with parallel light from a first spot lighting source 3, at the same time as a camera 4, preferably an electronic camera, records a

first image of said test surface 2, whereafter said first spot lighting source 3 is switched off and a second spot lighting source 5, adjacent to and parallel to said first spot lighting source 3, illuminates said test surface 2 at the same time as said camera 4 records a second image of said test surface 2. Thereby, the camera 4 is advantageously provided with an image modifying unit 6, which may comprise lenses, filters, polarizers or other elements, according to prior art, which may facilitate a subsequent image processing.

The first and second images are transferred to a central unit 7, provided with image analysis functions and control functions, which control both the spot lighting sources 3, 5 and the camera 4. In the central unit 7, said second image is subtracted from said first image by means of image processing, in order to provide a difference image, wherein surface defects, such as polishing roses, appear with a certain intensity corresponding to the degree of severity of said surface defects. The central unit 7 is advantageously arranged so that, when evaluating an obtained difference image, it is able to provide both a measure of the area of said surface defects, and a measure of the intensity of said surface defects, as has been mentioned earlier.

Fig. 2 shows an example of a difference image, which has been obtained by means of the method and the device according to the invention. The illustrated difference image should only be regarded as an example, and such a difference image can, with previously known technique, be visualized and clarified in many ways.

The equipment which constitutes the device according to the invention should otherwise be well-known to persons skilled in the art, and each component in itself is commercially

available, without implying that the inventive thought which is the basis of the present invention should be previously known.

The present invention is in no way limited to being performed according to the above-mentioned embodiments, or to what is shown in the attached drawings, but may be varied within the scope of the attached claims.

Accordingly, the camera or cameras used are not necessarily of an electronic type, such as a video camera (CCD), but it is also conceivable to photograph different partial images using a conventional camera and light sensitive film, and thereafter to scan these partial images into an image analyzer for separate image processing.

CLAIMS:

1. Method for measuring and quantifying surface defects on a test surface (2), using at least one light source (3, 5), at least one camera (4), and at least one central unit (7) having image analysis functions and control functions, characterized in that at least two partial images are recorded with at least one camera (4), during illumination of said test surface with parallel light or spot lighting, wherein the angle of incidence, in relation to said test surface (2) and/or the location of said camera (4) or cameras, is different when recording different partial images, whereafter the recorded partial images are processed in at least one central unit (7), whereafter one or several difference images are produced from said partial images, and said difference image or difference images are utilized for determining the degree of surface defect on the test surface (2).

2. Method according to claim 1, characterized in that said test surface (2), upon recording of a first partial image, is illuminated by a light source (3) placed in a first position, and that said test surface (2), when recording a second partial image, is illuminated by a light source (5) placed in a second position.

3. Method according to claim 1 or 2, characterized in that a first partial image of said test surface (2) is recorded by a camera (4), placed in a first position, and that a second partial image of said test surface is recorded by a camera (4), placed in a second position.

4. Method according to any one of the preceding claims, characterized in that said central unit(s) (7), on the basis of said difference image(s), provides a measure of the area of said surface defects, and a measure of the intensity of said surface defects, and that said measures are utilized for graduating the surface defects of said test surface (2).

5. Method according to any one of the preceding claims, characterized in that said surface defects on said test surface (2) essentially originate from polishing, rubbing or grinding.

6. Method according to any one of the preceding claims, characterized in that the position of the test surface (2) is changed between the recording of different partial images.

7. Method according to any one of the preceding claims, characterized in that said camera (4) simultaneously records several partial images through several different apertures or image registration apertures provided in said camera (4).

8. Method according to any one of the preceding claims, characterized in that an image modifying unit (6), comprising optical lenses, filters, polarizers or other elements, is used when recording a partial image in order to facilitate a subsequent image processing of (a) recorded partial image(s).

9. Method according to any one of the preceding claims, characterized in that a difference image is image-processed in said central unit (7) before a subsequent graduation of surface defects of said test surface (2), in order to facilitate the graduation.

10. Device for measuring and quantifying surface defects on a test surface (2), comprising at least one light source (3, 5), at least one camera (4), and at least one central unit (7) having image analysis functions and control functions,
c h a r a c t e r i z e d i n that said camera (4) or cameras and light source (3) or light sources (3, 5) are arranged for recording at least two partial images with different angle of incidence for incident light, that said central unit(s) is/are arranged for producing at least one difference image by means of subtracting one of said partial images from another of said partial images, and that said central unit(s) (7), on the basis of said difference image(s), has/have the ability to provide partly a measure of the area of said surface defects, and partly a measure of the intensity of said surface defects.

11. Device according to claim 10,
c h a r a c t e r i z e d i n that said camera (4) or cameras is/are provided with at least one image modifying unit (6), comprising optical lenses, filters, polarizers, or other elements which can facilitate a subsequent image processing of the recorded partial image(s).

12. Device according to claim 10 or 11,
c h a r a c t e r i z e d i n that the device (1) provides motion means for changing the position of the test surface (2) between the recording of different partial images.

13. Device according to any one of the preceding claims,
c h a r a c t e r i z e d i n that said camera (4) is provided with several different apertures or image registration apertures, which are able to record partial images with different angles of incidence for incident light.

14. Device according to any one of the preceding claims, c h a r a c t e r i z e d i n that said central unit (7) is arranged in order to image-process a difference image, before a subsequent graduation of surface defects of said test surface (2), in order to facilitate the graduation.

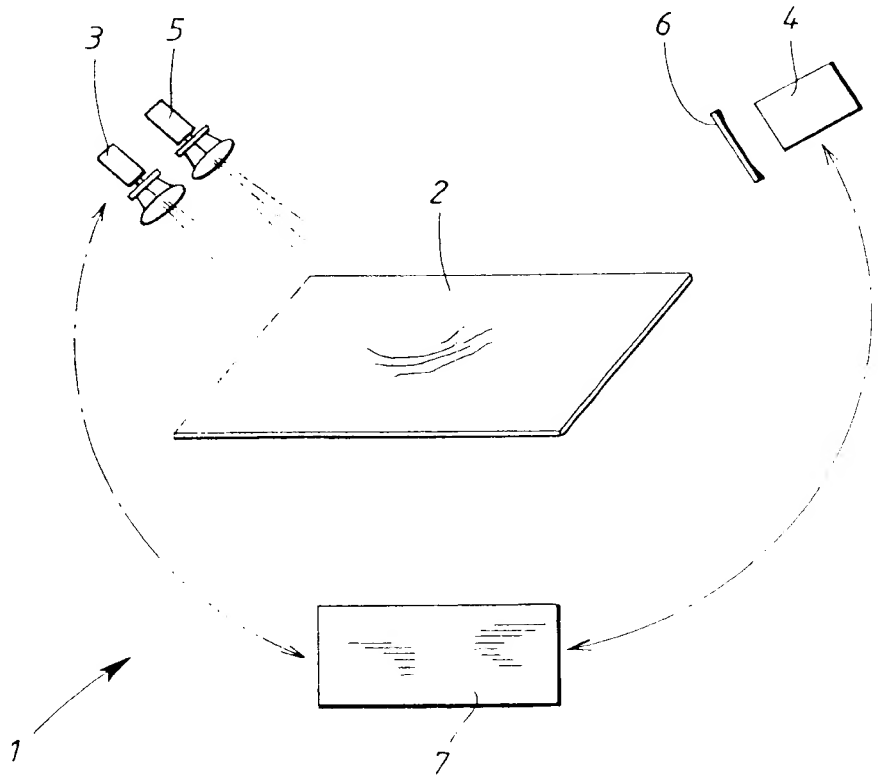

FIG. 1

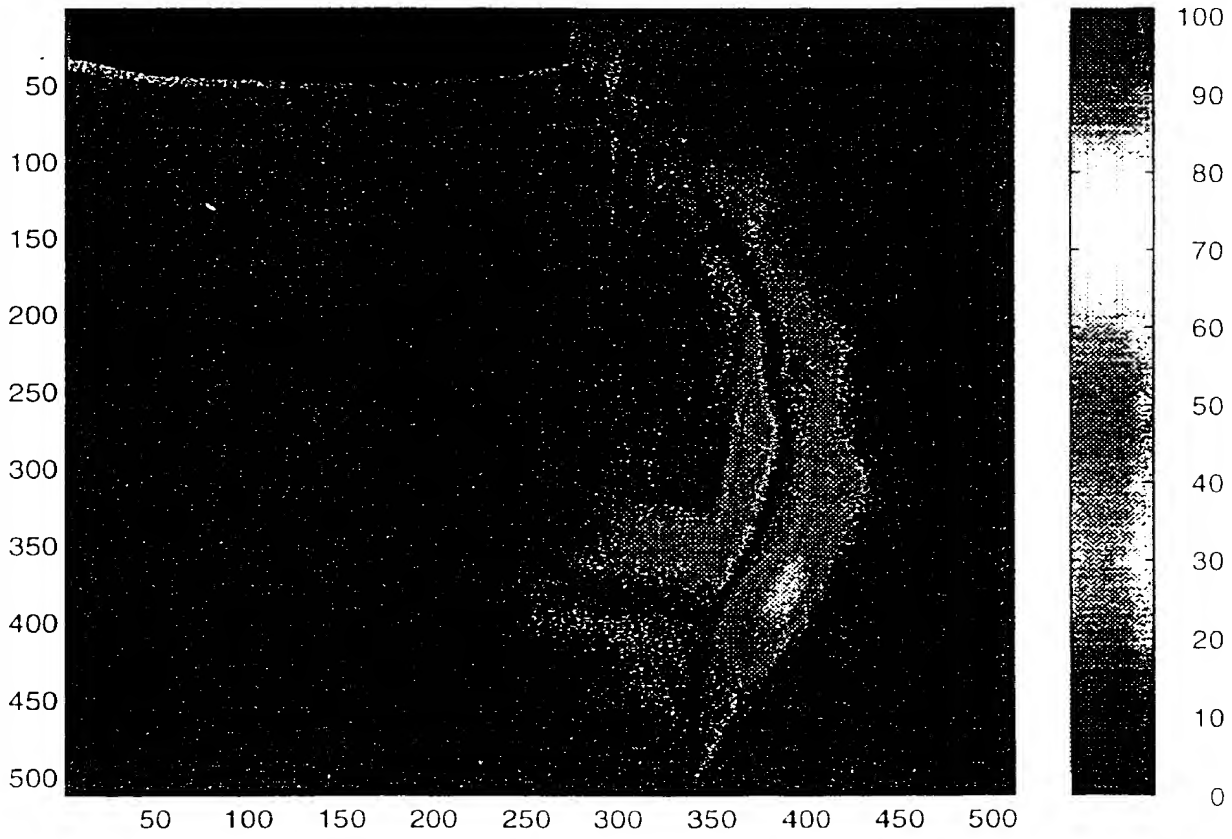
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FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/00226

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G01B 11/30, G01N 21/57, G01N 21/88
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G01B, G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4920385 A (DIFFRACTO LTD), 24 April 1990 (24.04.90), column 1, line 13 - column 23, line 49, figures 1-14B, claims 1,3,4,6-9,11, abstract --	1,10
A	US 5426506 A (THE UNIVERSITY OF CHICAGO), 20 June 1995 (20.06.95), column 6, line 4 - column 9, line 58, figures 1-3,6-12F, claims 1-17, abstract --	1,10
A	US 4162126 A (HITACHI,LTD.), 24 July 1979 (24.07.79), column 1, line 17 - column 8, line 18, figures 1,3, claims 1,3, abstract --	1,10

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
9 June 1998	11-06-1998
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/00226

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

29/04/98

International application No.
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